

# NAVAL POSTGRADUATE SCHOOL Monterey, California



**Report on the Office of Naval Research  
Phase II International Workshop on Shallow-Water Acoustics,  
Seattle, June 27, 1998**

by

Ching-Sang Chiu  
Warren W. Denner

September 1998

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September 1998

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## **Abstract**

Under the sponsorship of the Office of Naval Research Ocean Acoustic Program, U.S. and Asian Pacific Rim scientists have initiated a joint effort to design and conduct an international experiment to study shallow water acoustics, physical oceanography, and geology and geophysics in the China Seas. The joint planning began in the International Workshop on Shallow Water Acoustics, held on 8-9 December 1997 in San Francisco, California. The discussion was continued in the Phase II International Workshop on Shallow-Water Acoustics, held on 27 July 1998 at the Applied Physics Laboratory of the University of Washington, Seattle, Washington. Attended by 33 scientists representing China, France, Japan, Korea, Singapore, Taiwan, Russia and the U.S., the Phase II Workshop resulted in the establishment of a comprehensive list of experimental objectives and a preliminary experimental configuration. The Phase II Workshop also focused on site selection issues, narrowing the many previously discussed site options to only two choices. Based on scientific merits, the group's number one choice was the northern shelf of the South China Sea, with the shelf of the East China Sea selected as an alternate site. A plan of action was generated, calling for:

1. an international experiment to be carried out in April 2000,
2. our Chinese colleagues to apply to the appropriate Chinese authority for permission to conduct a collaborative scientific experiment in the South China Sea location,
3. each participating institution to provide a written summary of their research interest and resource commitment for the international experiment to the workshop organizers,
4. the Phase III workshop to be held in the near future to further coordinate the experimental effort.

This report summarizes the presentations, discussions and findings of the Phase II Workshop.



# 1 Introduction

In December 1995, under the sponsorship of the Office of Naval Research (ONR), a conference between U.S. and Chinese scientists was held at the Naval Postgraduate School in Monterey, California<sup>3</sup>. The purpose of the Monterey conference was to discuss the possibility of a joint U.S.-China shallow-water acoustic experiment. As an outcome of the Monterey Conference, a U.S.-China experiment sponsored jointly by ONR and the Chinese Academy of Sciences (CAS) took place in the central Yellow Sea in August 1996. Moreover, ONR and CAS also jointly sponsored the International Conference in Shallow Water Acoustics in April 1997 (SWAC'97) in Beijing<sup>4</sup> to expand the dialog and scientific exchange to include other countries in the Asian Pacific Rim. SWAC'97 was attended by more than 100 participants from many countries. These events led to the ONR International Workshop on Shallow Water Acoustics, held on December 8-9, 1997 in San Francisco, California<sup>5</sup>. At the San Francisco Workshop the participants agreed that it would be timely and appropriate to organize an international collaborative experiment involving the U.S. and other countries of the Asian Pacific rim. It was agreed that a second workshop would be needed to focus on the experimental design and scientific issues. This led to the Phase II Workshop reported here.

This report summarizes the presentations, discussions and findings of the workshop. The report has the following outline: The workshop goals, objectives and programmatic directions of the ONR Ocean Acoustics Program, as stated by Dr. Jeff Simmen are found in Section 2. Section 3 outlines the scientific issues and experimental plan prepared jointly by the Naval Postgraduate School (Drs. Ching-Sang Chiu and Steve Ramp) and the Woods Hole Oceanographic Institution (Drs. James Lynch, Robert Beardsley and Glen Gawarkiewicz). Section 4 reviews the presentations by the representatives. Input from the participants on scientific objectives, topics of interest, and resource availability from their institutions is summarized in Section 5. The conclusions of the Workshop are given in Section 6. The Agenda of the workshop is provided in Appendix A and a list of attendees is provided in Appendix B.

## 2 Goals and Objectives

Dr. Simmen opened the Workshop by reviewing the events leading up to this meeting, and stating that the long-term objective is to have a collaborative international experiment in the Spring of 2000 in the Asian Pacific Rim. The collaboration may involve participants from the U.S., China, Japan, Korea, Russia, Singapore, Taiwan, and India. Dr. Simmen emphasized that this would not be an experiment funded only by the U.S., but a true collaboration depending on shared resources, costs, data and results. The goals of this Workshop are:

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<sup>3</sup> Chiu, C.-S. and W. W. Denner, "Report of the Office of Naval Research USA-China Conference on Shallow-Water Acoustics, December 19-21, 1995," NPS Technical Report NPS-OC-97-001, January 1997.

<sup>4</sup> "Shallow-Water Acoustics," Editors: R Zhang and J. Zhou, China Ocean Press, 1997.

<sup>5</sup> Chiu, C.-S. and W. W. Denner, "Report on the Office of Naval Research International Workshop on Shallow-Water Acoustics, San Francisco, CA, 8-9 December 1997," NPS Technical Report NPS-OC-98-002, March 1998.

1. develop an outline of the experimental design,
2. determine who wants to participate,
3. develop a list of scientific interests and resources that would be available.

He thanked the participants for attending the Workshop and indicated that funding contribution to support such an experiment on the U.S. side had been programmed into the ONR budget. He also indicated that the potential experiment would be multi-disciplinary in nature, and that other programs in ONR would provide support (e.g., Marine Geology and Geophysics, and Physical Oceanography).

### **3 Scientific Issues and Experimental Plan**

Dr. Ching-Sang Chiu presented an overview of the environmental setting of two possible areas for the experiment. These were the northern shelf of the South China Sea, and the middle-to-outer shelf of the East China Sea. He stressed that the South China Sea location is both oceanographically and acoustically interesting. It is an area of multiple fronts and water masses, large river outflow from the Pearl River, and according to satellite data, strong but orderly internal wave fields that are resolvable. Other important aspects of the South China Sea location are: It is close to excellent logistic bases for staging the experiment and there are ongoing experiments in the same area collecting highly complimentary data.

Dr. Tony Liu presented an overview of satellite remote sensing of both areas. He pointed out that imagery of the South China Sea showed strong internal wave and soliton fields, but that seemed to emanate from well-defined source regions. In contrast he showed that the East China Sea contained very confused and overlapping internal wave fields.

Dr. Tswen Yung Tang discussed ongoing collaborative research between Taiwan and China in the South China Sea. This collaboration is part of the International South China Sea Monsoon Experiment. It involves several fixed moorings as well as dedicated shipboard surveys. He discussed some of the up-to-date scientific results as well as the problems that they have experienced in protecting the moorings while working in this area. A journal article is in preparation and data exchange between Taiwan and China is scheduled for September in Guangzhou, China.

Dr. Joe Kravitz, from ONR, presented some very important bottom and sub-bottom data collected in the South China Sea and East China Sea. This data had been collected and analyzed by two of his principal investigators. The sub-bottom data in the East China Sea shows a more complex structure than does the data from the South China Sea.

Dr. Jixun Zhou presented some thoughts on bottom interaction studies and past shallow-water acoustic research carried out in China. He pointed out the mutual advantages to an U.S.-China collaboration in this area.

Dr. Jim Lynch presented the outline of a draft experimental plan that was jointly developed by the Naval Postgraduate School (Drs. Ching-Sang Chiu and Steve Ramps), Woods Hole Oceanographic Institution (Drs. Jim Lynch, Robert Beardsley and Glen



Gawarkiewicz) and the Naval Research Laboratories (Dr. Marshall Orr) for the South China Sea location. Serving as a working concept to be considered, revised and enhanced by the international participants, the NPS-WHOI-NRL plan proposes a coupled acoustic and oceanographic experiment in the vicinity of the shelfbreak to address both shallow-water acoustics and physical oceanography scientific issues. The acoustic issues include:

- Understand sound propagation along & across multiple fronts.
- Investigate the scattering effects of the linear and non-linear internal waves.
- Examine the acoustic effects of a strong fresh-water plume.
- Investigate the forward scattering properties of bottom inhomogeneities.
- Understand the geological and acoustical signature of stratigraphy produced by river sedimentation.
- Investigate directional reverberation in an inhomogeneous medium (ocean and bottom).
- Investigate properties of the coastal ambient noise field.
- Investigate higher frequency coastal acoustics ( $f > 1000$  Hz).
- Investigate horizontal array coherence, as well as vertical and temporal coherence.
- Can we learn to model and predict these effects?

The physical oceanographic issues include:

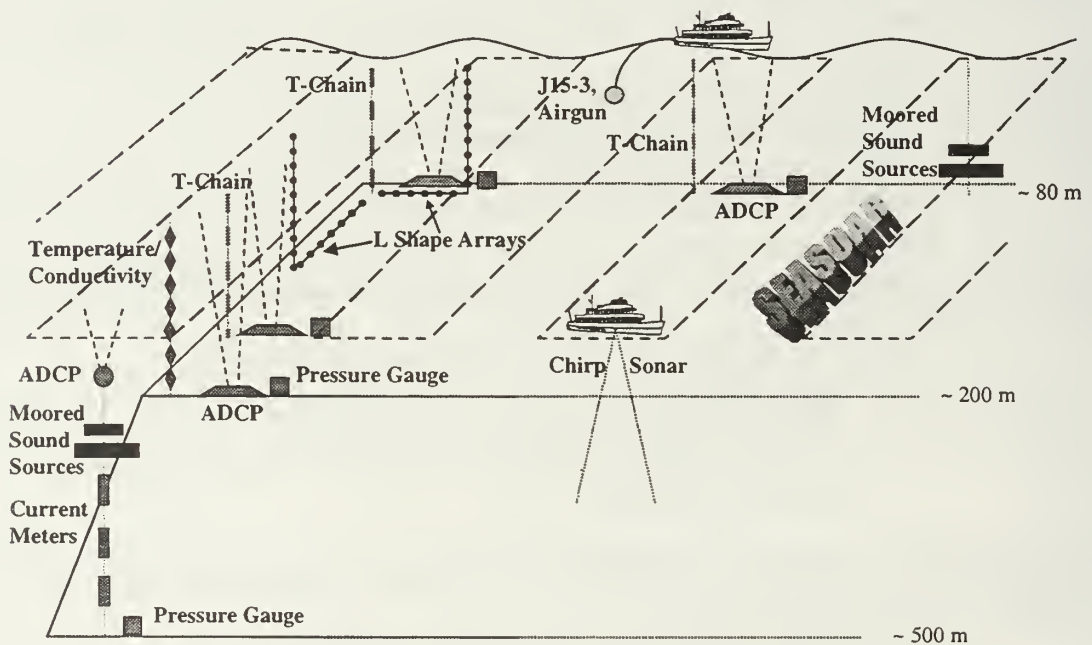
- Describe the strength, transport, and space-time variability of the three major currents:
  - Guangdong Coastal Current (GCC)
  - South China Sea Warm Current (SCSWC)
  - Kuroshio Intrusion (KI)
- Describe the strength, stability, and vertical motions associated with the fronts between these currents.
- Obtain a first look at the internal wave field on the continental shelf southeast of China.
- Understand the dynamics of the currents in association with:
  - Local wind stress
  - Along and across-shore pressure gradients
  - Coastally-Trapped Waves
  - Buoyancy Injection

The NPS-WHOI-NRL plan also consists of a preliminary experimental design which include the following elements:

- Multi-static propagation and reverberation experiments
  - Moored (multi-frequencies), towed & explosive (broadband) sources
  - horizontal and vertical line arrays and/or L arrays
- Bottom characterization
  - Chirp sonar, Airgun & towed J15-3 (sub-bottom acoustic)
  - Corer and Graber
- Long-term current, temperature, and salinity moorings (e.g., Pettigrew et al. and other concurrent projects)
- Short term, high resolution current, temperature, and salinity moorings

- Current meters, ADCPs
- Thermistor Chains
- High resolution towed profiling CTD observations
- Satellite remote sensing
- Numerical modeling, both physical oceanography and acoustics

The schematic of such a design is shown in Figure 1. It is important to note that this preliminary design was developed based only on resources that can be made available by NPS, WHOI and NRL. Thus, the inclusion of the international assets as well as assets from the other U.S. institutions will greatly enhance the present experimental objectives and design, making it the most comprehensive shallow-water acoustic experiment in present days. It is also important to note that, while the acoustic objectives outlined by NPS, WHOI and NRL are almost entirely transportable to the East China Sea location, the physical oceanographic objectives are not.



**Figure 1. The NPS-WHOI Generic Sampling Plan for a Shelfbreak Coupled Ocean/Acoustic Field Experiment.**

## 4 Participant Input

Dr. Robert Spindel, of the Applied Physics Laboratory, University of Washington (UW/APL) acted as the discussion leader to gather the input to the scientific plan outlined above. The following are remarks and input provided by the participants.

Dr. Glenn Gawarkiewicz, from WHOI, pointed out that there had been fewer process-oriented studies in the South China Sea, and that fact, in his mind, was a strong motivator to select the South China Sea region for the experimental site. In addition, he felt that the current systems and mesoscale variability provided a different setting than previous shallow water acoustic experiments. He suggested that WHOI had a SeaSoar that would be available for the experiment.

Dr. Eng-Soon Chan, from the National University of Singapore, supported the South China Sea as the site, and indicated that Singapore would have significantly less interest in the East China Sea site.

Dr. Bill Kuperman, of Scripps Institution of Oceanography (SIO), stressed an interest in reverberation and coherence. He suggested that MPL could bring a number of arrays (500Hz, 3500Hz, and 20kHz) as well as oceanographic sensors to the experiment. Another subject of interest is phase conjugation. Dr. Bruce Cornuelle, also from SIO, (Dr. Peter Worcester's substitute) suggested that they could bring a 2 kHz broadband source and tomography equipment similar to that used in their Mediterranean experiment.

Dr. Marshall Orr, from the Naval Research laboratories (NRL), stated that they had two primary interests, signal processing/coherence and reverberation/matched field processing. Dr. Orr said that NRL had a significant amount of equipment that could be available for the experiment. He provided a list.

Dr. Jixun Zhou, of Georgia Institute of Technology, indicated a broad interest in all the data collected during the experiment. His primary interest was in coherence, in particular ping-to-ping time coherence. He voiced interest in reverberation and inversion of bottom properties. Dr. Zhou indicated that Georgia Tech. had some unique sources that could be put together to form a flexible source array.

Dr. Tswen Yung Tang, of National Taiwan University, said that they wanted to participate and that they could make available a research vessel, and a SeaSoar. Also, their moorings in the South China Sea would be available.

Dr. Robert Spindel indicated that APL had a strong interest in reverberation and bottom structure.

Prof. Renhe Zhang, of the Chinese Academy of Sciences, said that the Acoustics Institute was interested in the acoustic inversion of bottom parameters, the directional properties of the noise field, the depth dependence of reverberation, the interaction of internal waves and acoustics, and the acoustic impact of circulation features. He indicated that China had two research vessels that would be available for the experiment.



Dr. Arata Kaneko, from the Hiroshima University of Japan, indicated that their primary interest was in the East China Sea and if the experiment took place there he might be able to offer a research vessel for participation. His primary technical interest is in acoustic tomography. He also has a towed fish with an ADCP that could be made available for the experiment. JAMSTEC might want to participate and Kaneko offered to coordinate their participation.

Mr. Shunji Ozaki, of Japan's OKI Electric Industry Co. Ltd., indicated that his primary interest was in bottom reverberation.

Dr. Jungyul Na, of the Hanyang University, indicated that Korea already had major ongoing field efforts in the Yellow Sea and Sea of Japan. Korea's interest would be primarily in the East China Sea. However, he would be willing to participate as an individual scientist for a South China Sea experiment.

Dr. Victor Akulichev, of the Pacific Oceanological Institute, indicated that Russia could make available a research vessel. They also have sources that operate at various parts of the acoustic spectrum and autonomous sources that could be brought to the experiment.

Associate Professors Li Xiukun and Li Donglin represented Professor Yang Shi-e, of the Harbin Engineering University (HEU) of China. Professor Yang sent a prepared statement:

“We are interested in participating in a joint experiment, and can provide some resources. Because this experiment would likely be multi-disciplinary, it is very important to indicate the proper site. The sites should fit for various interests, we think that selecting two areas are better. One in the East China Sea (125 E and 27 N) and another in the South China Sea (119 E and 22 N). Both areas are at the boundary of the continental shelf with distinguishing bottom slope, and complex oceanographic conditions. With the first area there is Kuroshio from the Pacific Ocean to the East Sea, which processes great difference from surrounding seawaters in temperature and salinity. There also exist strong internal waves. So propagation of sound in this area will be very complex and challenging. I think that some new phenomena about sound propagation can be obtained in these areas.”

Professor Yang indicated that HEU would be most interested in sound propagation anomalies in each area in the frequency range of several hundred hertz to five kilohertz. They are also interested in seabed scattering and bottom reverberation, ocean ambient noise, and oceanographic conditions. HEU has a low frequency transmitter, multichannel recorders, and various hydrophones and cables.

## 5 Conclusions

The Phase II workshop, to plan a coupled shallow-water acoustics and oceanography international experiment, was held on 27 June 1998 at the Applied Physics Laboratory of



the University of Washington. Thirty-three scientists representing China, France, Japan, Korea, Singapore, Taiwan, Russia and the U.S. attended the workshop. At the workshop an experimental plan to study sound propagation, ocean processes and bottom structure was outlined.

Two primary sites for the experiment were discussed in detail. One on the shelf of the North South China Sea, and one in the East China Sea. Both of these areas offer unique scientific opportunities, and an experiment in either site could be justified on a scientific basis. However, the majority of the participants favored the shelfbreak area of the North South China Sea as the preferred site. Most of the participants indicated that they would participate in an experiment at either site.

A plan of action was generated. It consisted of the following action items:

1. The international experiment would be carried out in April 2000.
2. The Chinese colleagues should apply to the appropriate Chinese authority immediately for permission to conduct a collaborative scientific experiment in the South China Sea location.
3. Each participating institution should provide a written summary of their research interest and resource commitment for the international experiment to the workshop organizers.
4. A Phase III workshop should be held in the near future to further the coordination the experimental effort.

The scientific interests represented at the workshop were indeed very broad, making the proposed experiment very comprehensive. Some of the primary themes involved measurements to study the mesoscale dynamics (fronts and eddies), major circulation features, bottom structure and sedimentation, internal waves, acoustic propagation across multiple fronts, acoustic propagation in strong internal wave and solution fields, bottom scattering, reverberation, signal coherence, signal processing techniques and inversions. The participants collectively offered an array of modern oceanographic and acoustic instrumentation that has never before been dedicated to a single experiment, certainly not in that part of the world. A successful experiment would make a significant contribution to our understanding of the oceanography of this region, which could have long term benefits to the Chinese and other partners of the Asian Pacific Rim, as they develop the renewable and non-renewable resources of this area, and contend with the positive and negative impacts of those developments.

## **6 Acknowledgements**

It is with great pleasure that we gratefully acknowledge Dr. Bob Spindel for hosting the Workshop and leading the group discussions. Special thanks go to Ms. Piper Magallanes and Mrs. Margie Denner for their flawless administrative assistance. Finally, the Workshop would not have been possible without the creativity and financial support of Dr. Jeff Simmen of the Office of Naval Research as well as the enthusiastic participation of the delegations from the seven countries.



## **Appendix A: Workshop Agenda**

**June 27, 1998**

0800-0830	Registration
0830-0840	Opening and administrative remarks – Spindel/Denner
0840-0850	Meeting goals and objectives – Simmen
0850-0915	Overview – Chiu
0915-0930	Remote Sensing Data - Liu
0930-0945	South China Sea Monsoon Project Discussion - Tang
0945-1000	Geological Setting Discussion - Kravitz
1000-1030	Coffee Break
1030-1100	Scientific Objectives and Experimental Framework – Lynch
1100-1200	Other Issues - All
1200-1300	Lunch
1300-1430	Design experimental configuration – All
1430-1600	Outline logistic support and issues – All
1600-1700	Outline a plan of action – All
1700	Adjourn



## Appendix B: List of Attendee

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